Reveals the otherwise invisible Universe

- to see ***the dawn of black holes***,
- reveal ***what drives galaxy formation and evolution***, and
- unveil ***the energetic side of stellar evolution and stellar ecosystems.***

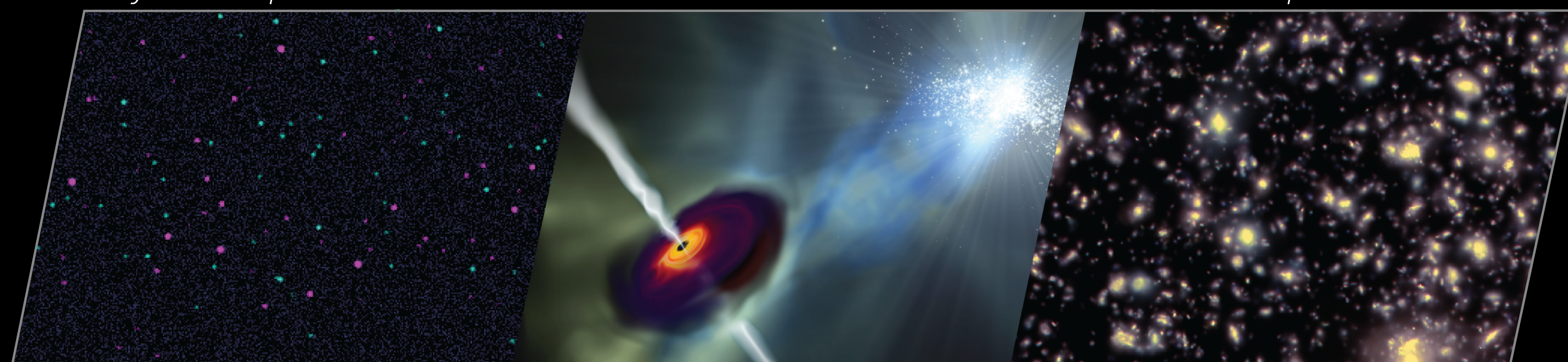
X-RAY OBSERVATORY

LYNX

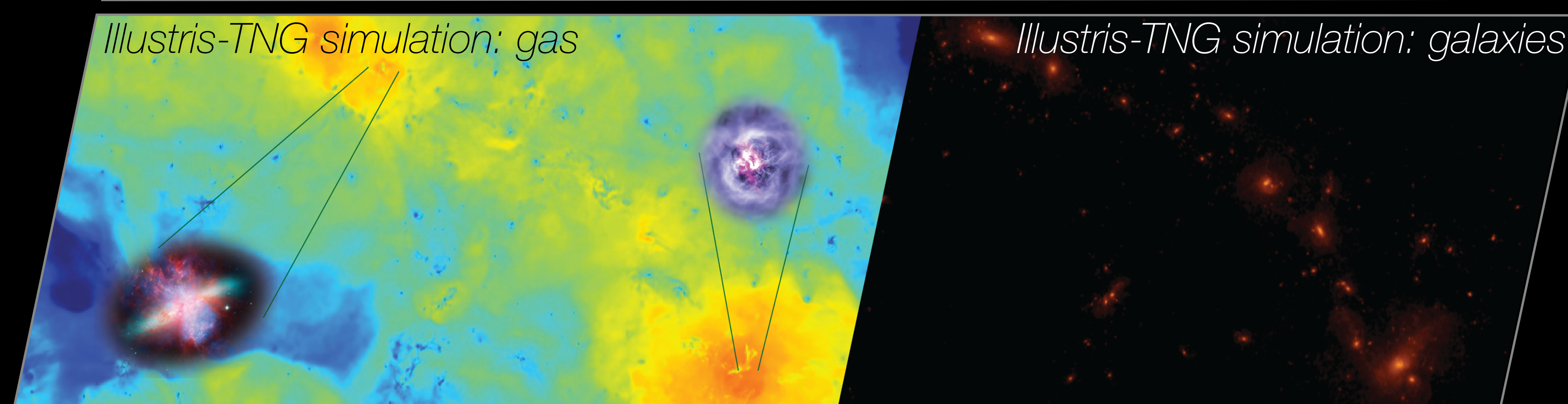
The Dawn of Black Holes

Lynx deep field

JWST deep field



The Invisible Drivers of Galaxy and Structure Formation

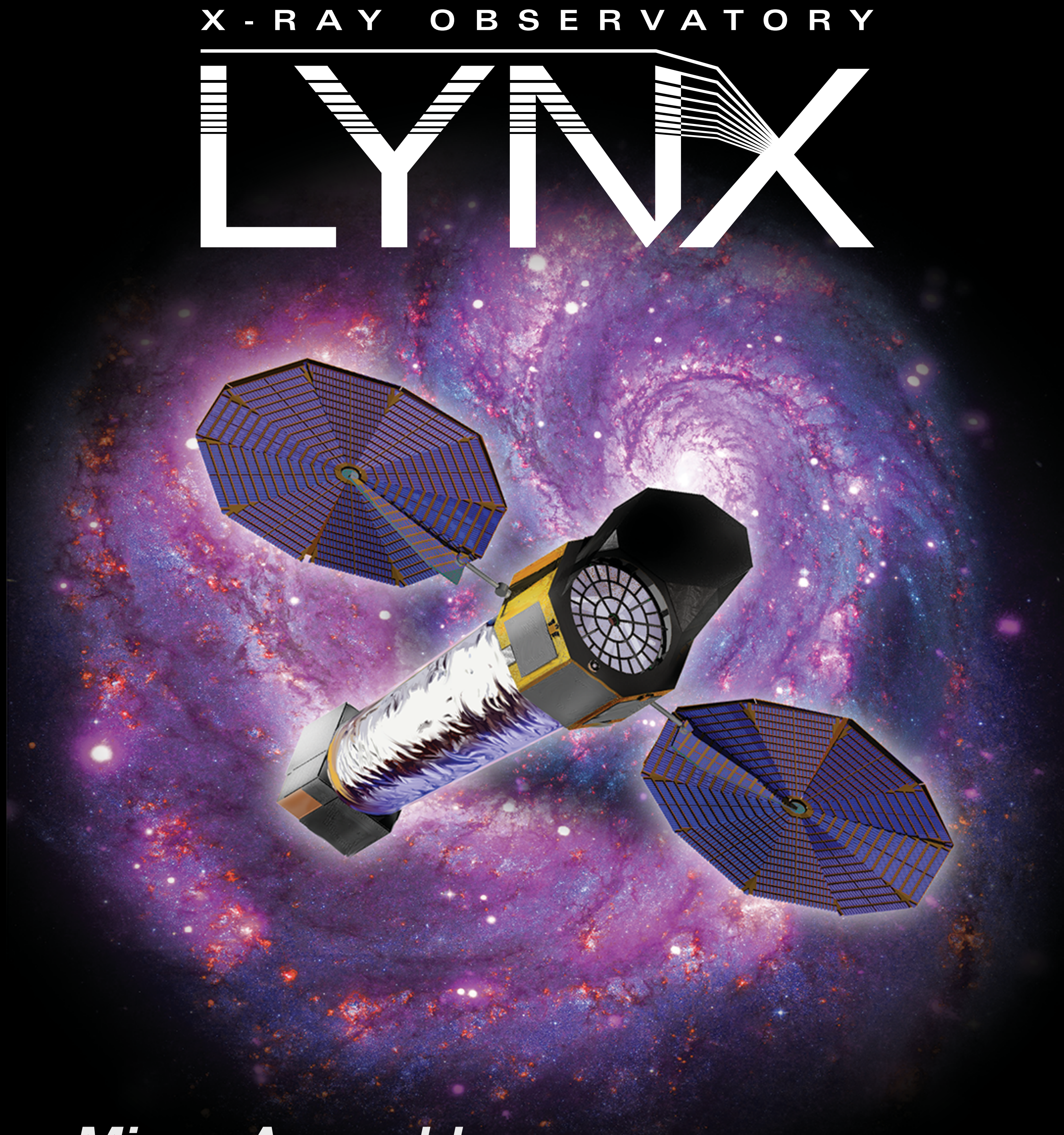


The Energetic Side of Stellar Evolution and Stellar Ecosystems

Endpoints of stellar evolution

Stellar birth, coronal physics, feedback

Impact of stellar activity on habitability of planets



High-definition X-ray imager

- Silicon sensors with ~0.3″ pixels, closely following the optimal focal surface. FOV ≥ 20′×20′.
- $\Delta E \sim 100$ eV over 0.1–10 keV band.
- High frame rates to minimize pile-up.

X-ray microcalorimeter

- The main array provides non-dispersive spectroscopy with $\Delta E < 3$ eV over the 0.2–7 keV band and imaging with 1″ pixels over a 5′×5′ FOV.
- Several subarrays are optimized for sub-arcsec imaging, 0.3 eV energy resolution, and coverage of 20′×20′ FOV.

Mirror Assembly

- Densely packed, thin, grazing incidence mirrors.
- Outer diameter of 3m and effective area > 2 m^2 at 1 keV.
- 0.5″ on-axis PSF (50% power diameter).
- Sub-arcsec PSF out to 10′ off-axis.

X-ray grating spectrometer

- Resolving power $\lambda/\Delta\lambda > 5000$
- Effective area > 4000 cm^2 covering X-ray emission and absorption lines of C, O, Mg, Ne, and Fe-L.

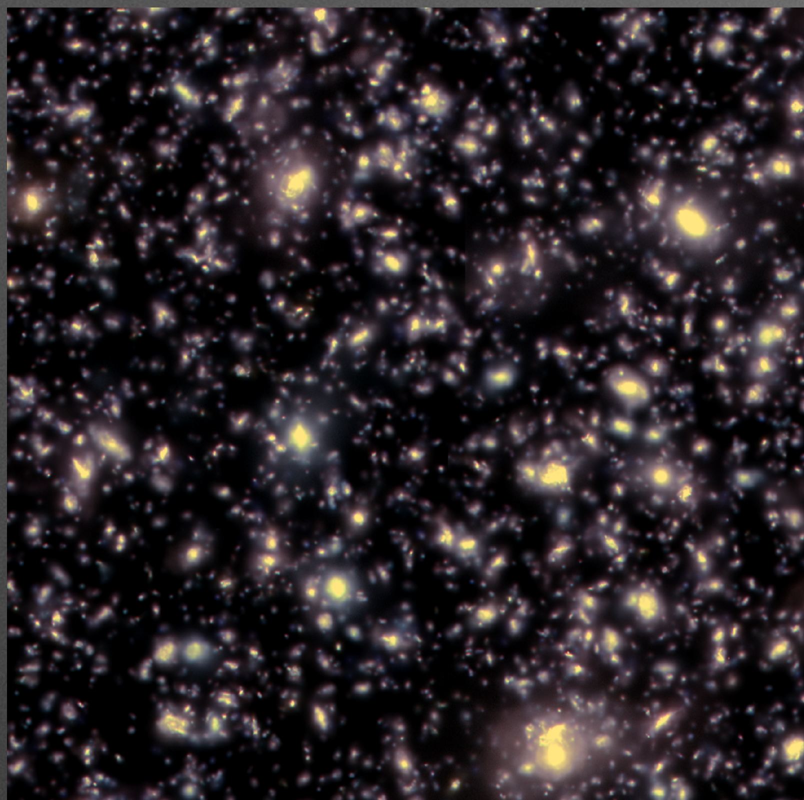
Leaps in capability over *Chandra* and *ATHENA*:

- 50× increase in sensitivity via coupling superb angular resolution with high throughput;
- 16× larger field of view for sub-arcsecond imaging, leading to a 800× faster survey speed;
- 10–20× higher spectral resolution for both point-like and extended sources.

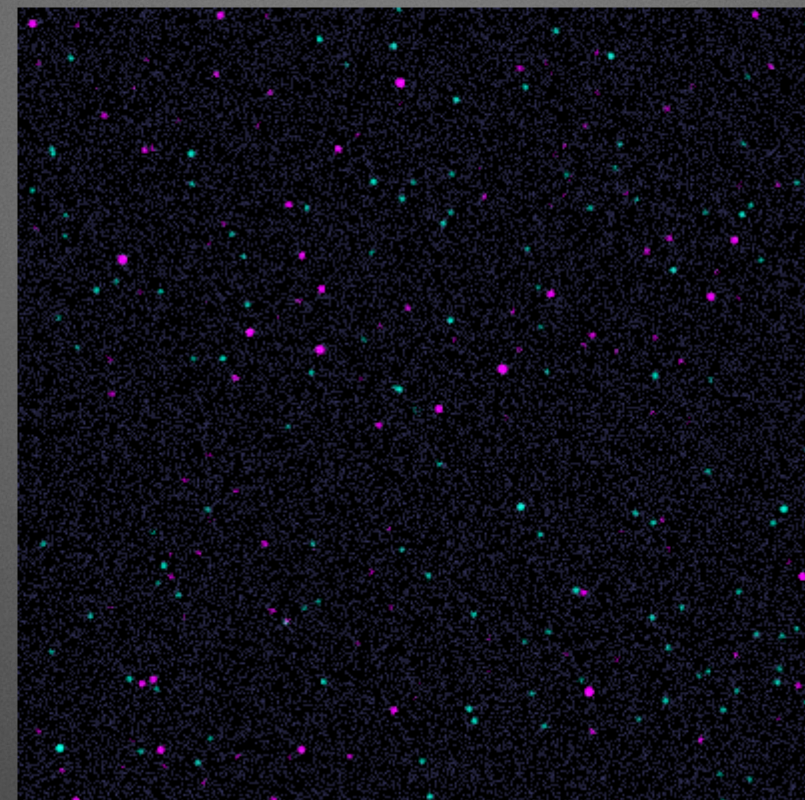
The Dawn of Black Holes

Simulated 2’×2’ deep fields:

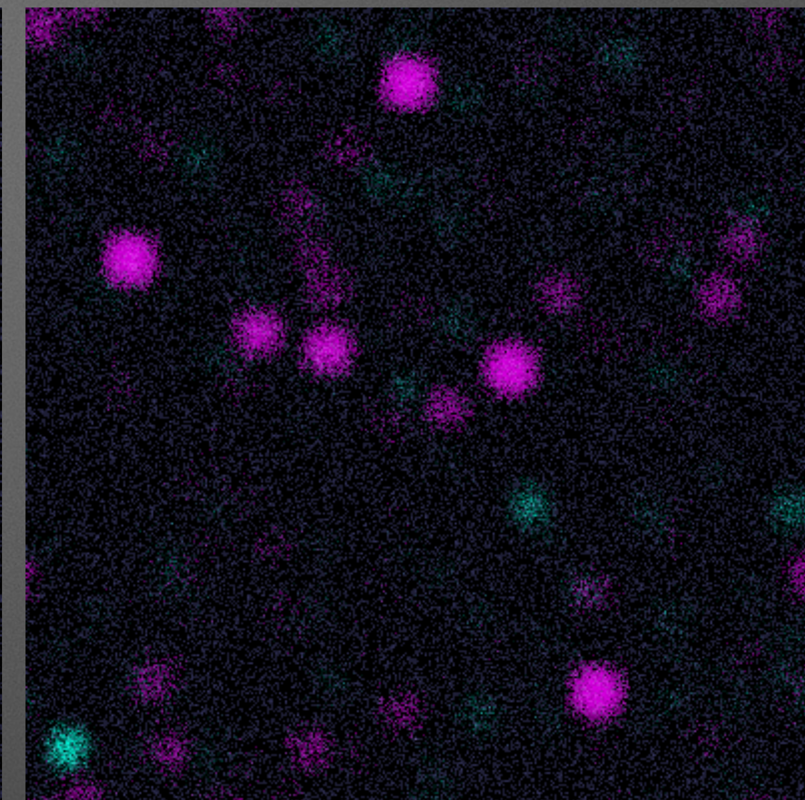
JWST (Illustris-TNG light cone)



Lynx (purple = AGNs, green=galaxies)



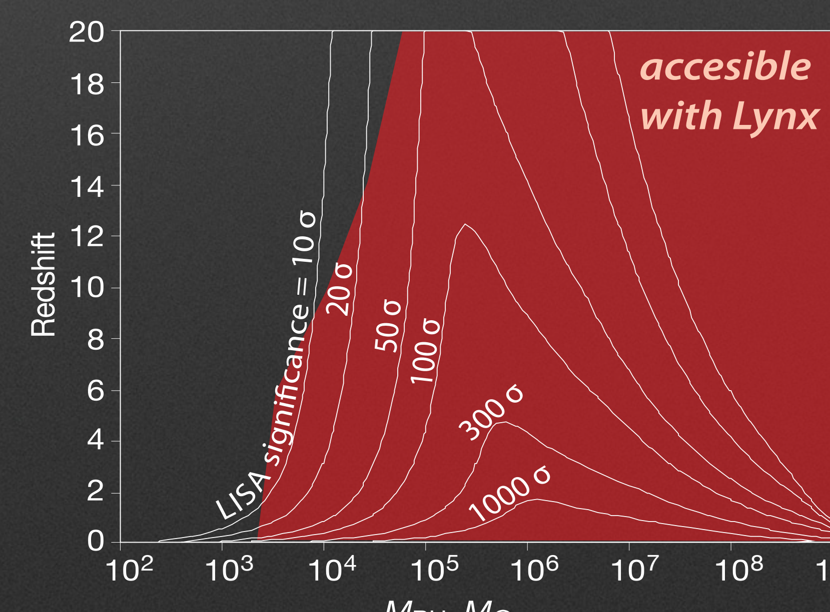
Athena (5” PSF, same area as Lynx)



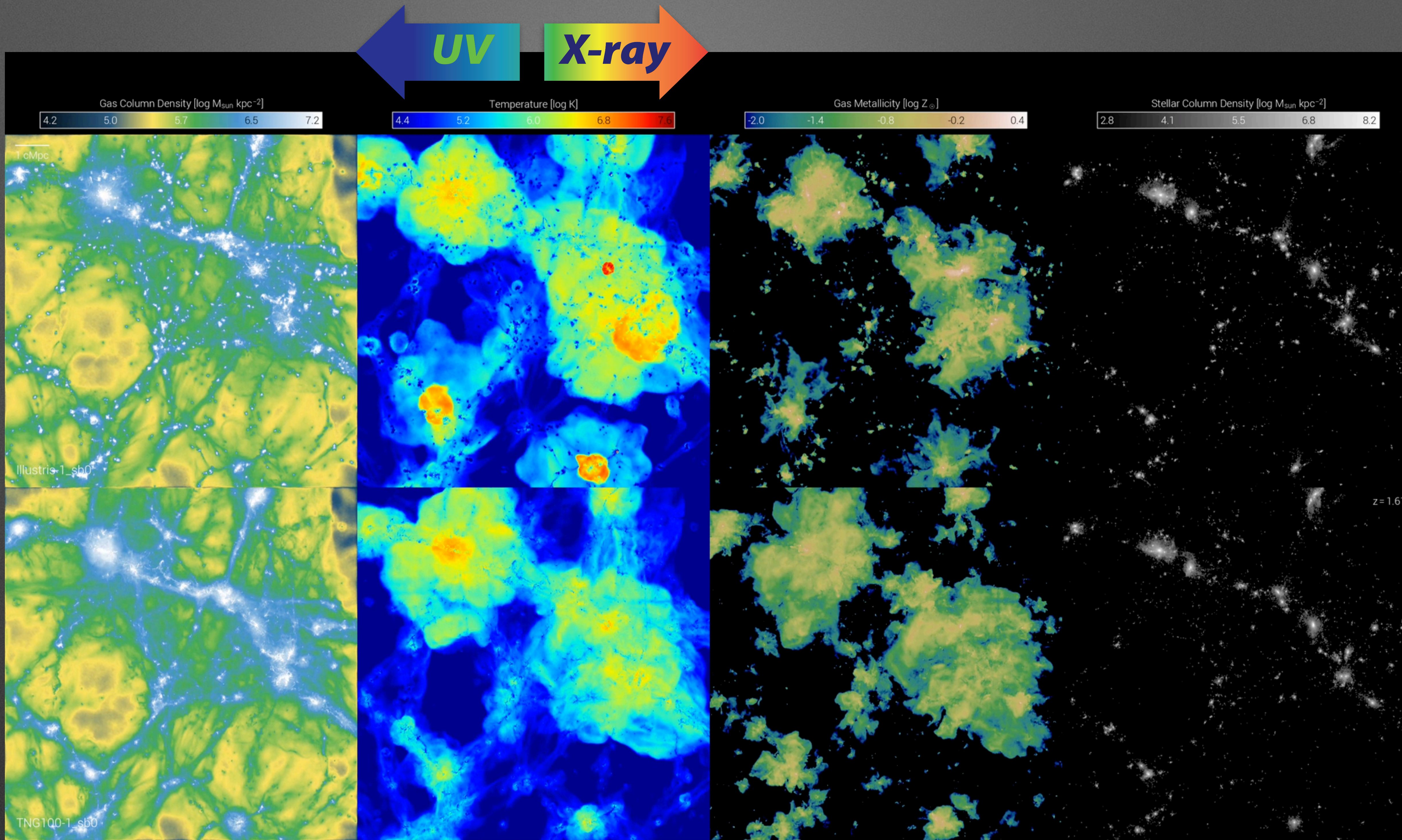
Lynx will find the first supermassive black holes in the first galaxies detected by JWST, trace their growth from the seed phase, and shed light on how they subsequently co-evolve with the host galaxies. Needed sensitivities, 10^{-19} erg/s/cm^2, are ~ 200× below *ATHENA* confusion limit.

Synergies with gravitational wave experiments:

- Similar parameter space is covered at high-z. *Lynx* is sensitive to black hole growth through accretion (dominant mode).
- *Lynx* can respond to high-significance LISA triggers of SMBH mergers at z<2, localized to 1–10 deg^2 days before the merger. *Lynx* observations will establish how accretion proceeds in pre-merger BH binaries.



The Invisible Drivers of Galaxy and Structure Formation



Illustris

Illustris TNG

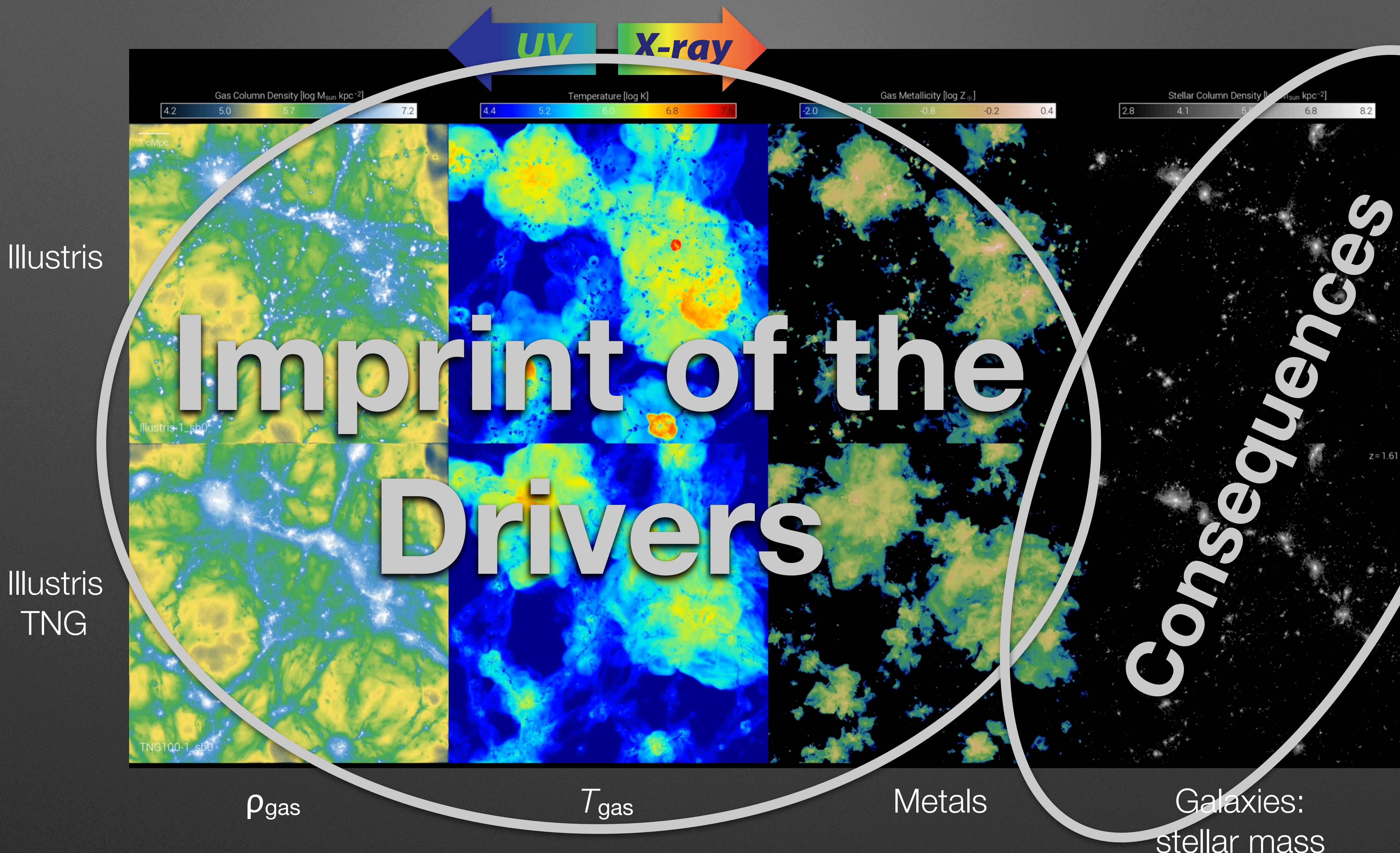
ρ_{gas}

T_{gas}

Metals

Galaxies: stellar mass

The Invisible Drivers of Galaxy and Structure Formation



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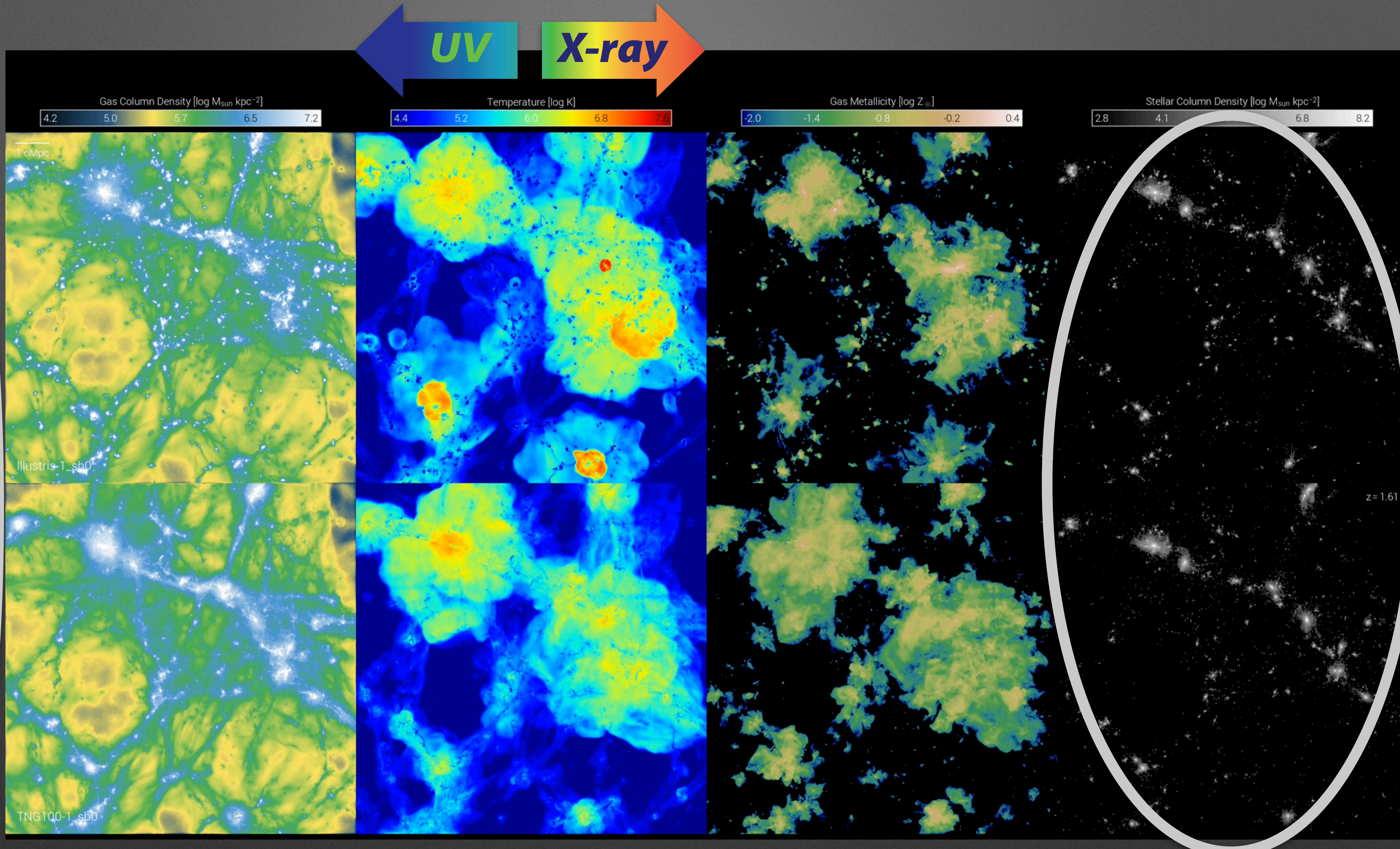


Illustris

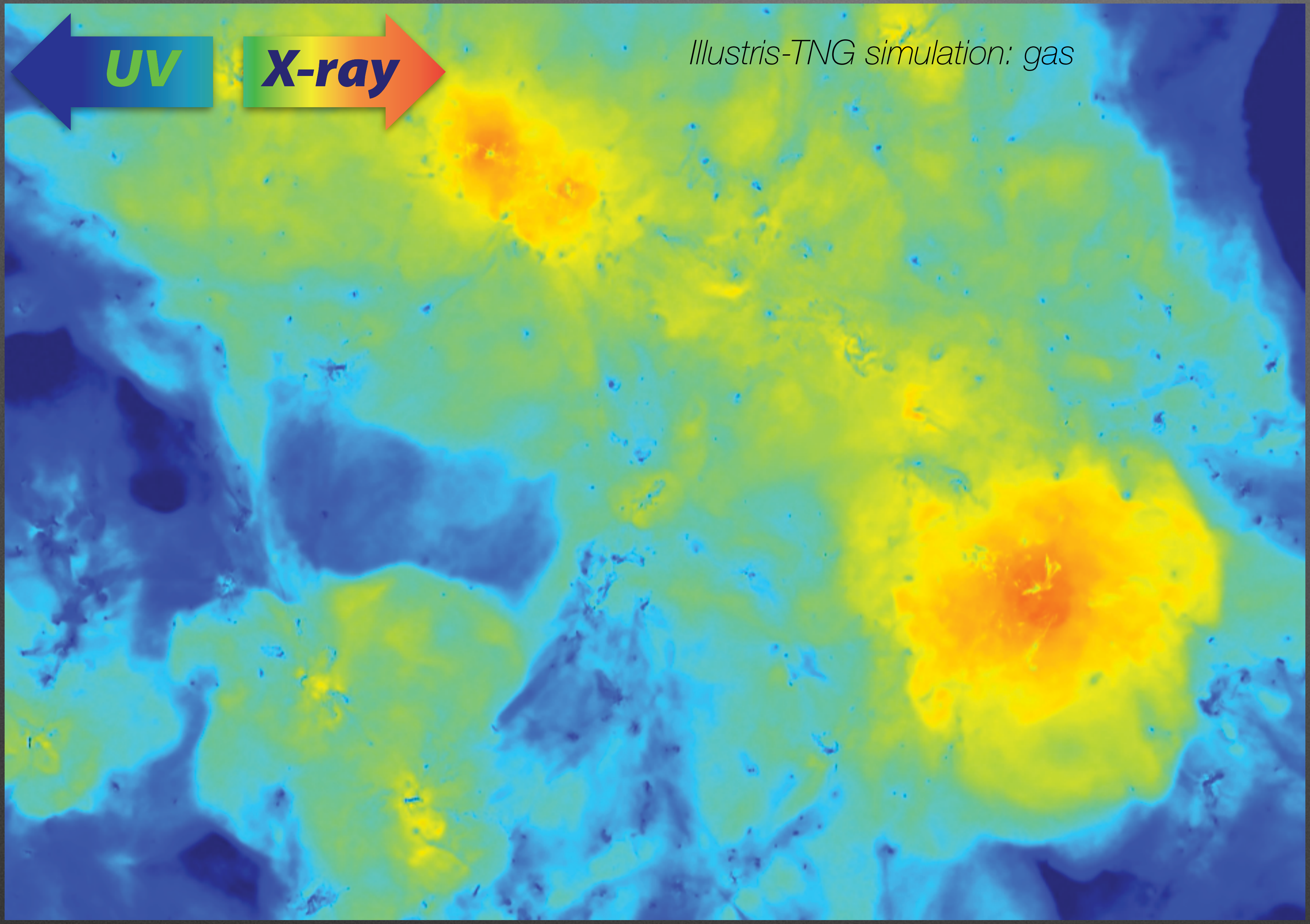
Illustris TNG

ρ_{gas} T_{gas} Metals

Same numerics, different physics

Indistinguishable galaxies

The Invisible Drivers of Galaxy and Structure Formation



The assembly, growth, and state of visible matter in cosmic structures are largely driven by violent processes that produce and disperse large amounts of energy and metals into the surrounding medium. In galaxies at least as massive as the Milky Way, the relevant baryonic component is heated and ionized to X-ray temperatures. Only *Lynx* will be capable of mapping this hot gas around galaxies and in the Cosmic Web, as well as characterizing in detail all significant modes of energy feedback. *Essential observations will require high-resolution spectroscopy (R ~ 5000) of background AGNs, the ability to detect low surface brightness continuum emission, and R ~ 2000 spectroscopy of extended sources on arcsecond scales — all unique to Lynx.*

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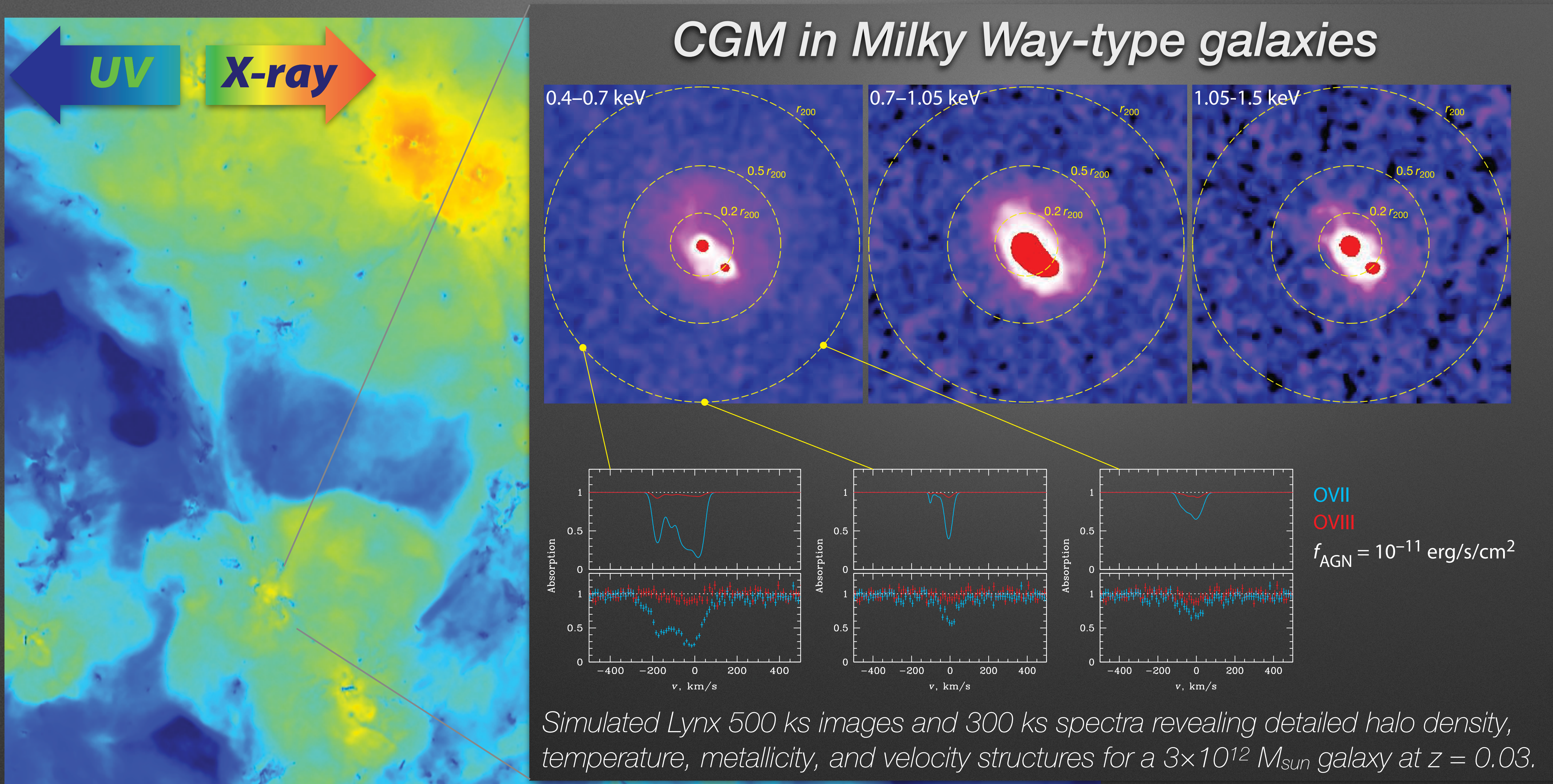

Simulated Lynx 500 ks images and 300 ks spectra revealing detailed halo density, temperature, metallicity, and velocity structures for a 3×10^{12} M_{sun} galaxy at $z = 0.03$.

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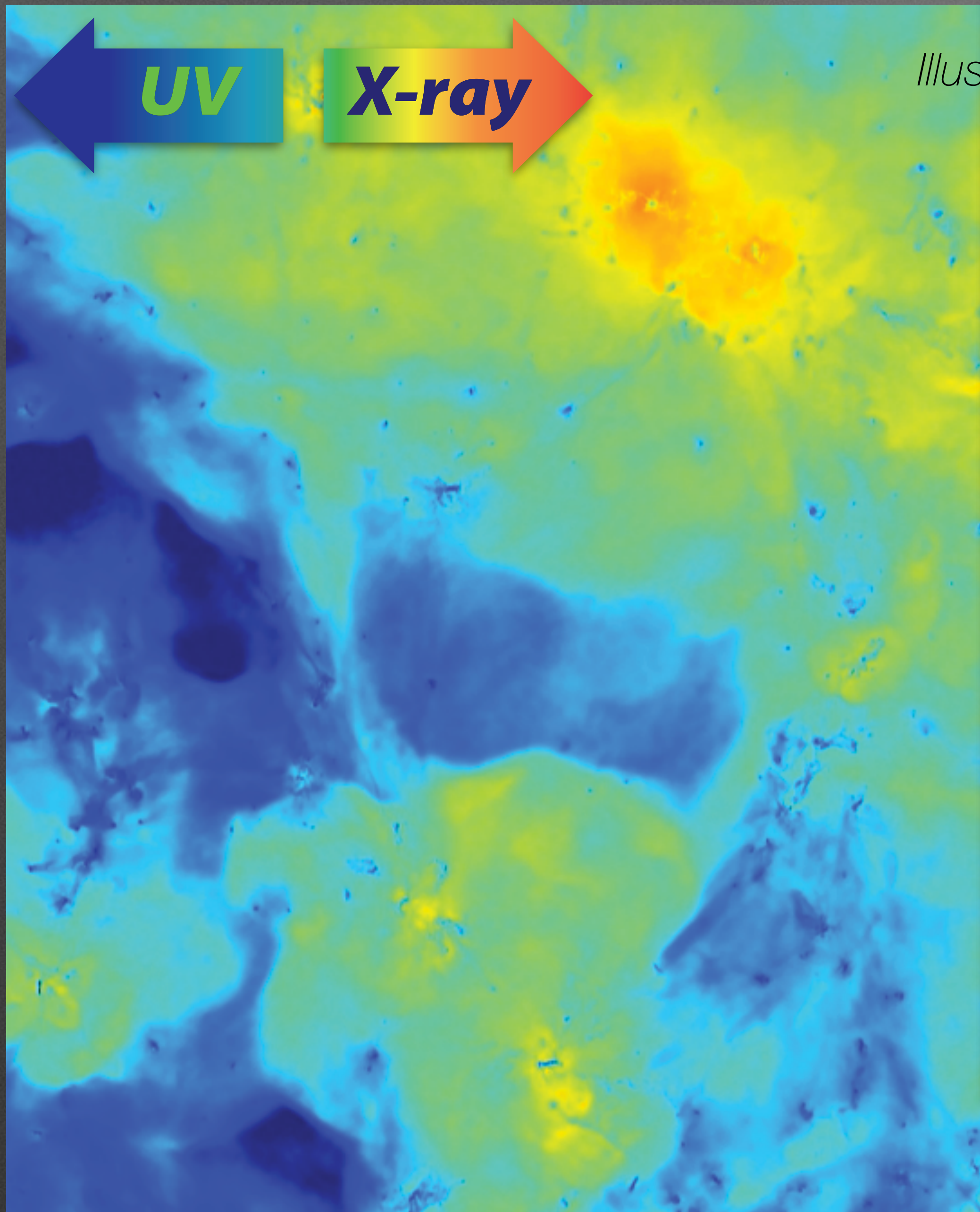
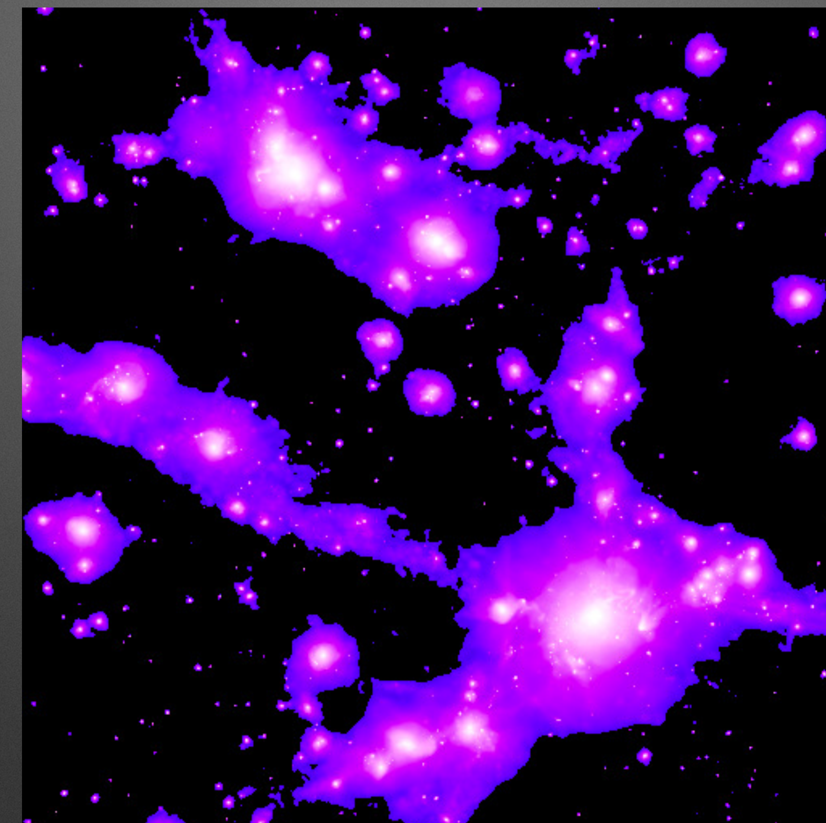


Cosmic Web



Lynx will be able to map the Cosmic Web at thresholds of $\rho/\rho_{mean} > 30$ and $T > 1.5{\times}10^6$ K. A simulated 25 Mpc box is clipped at the Lynx sensitivity in a 10 Msec survey of a 10 deg2 region.

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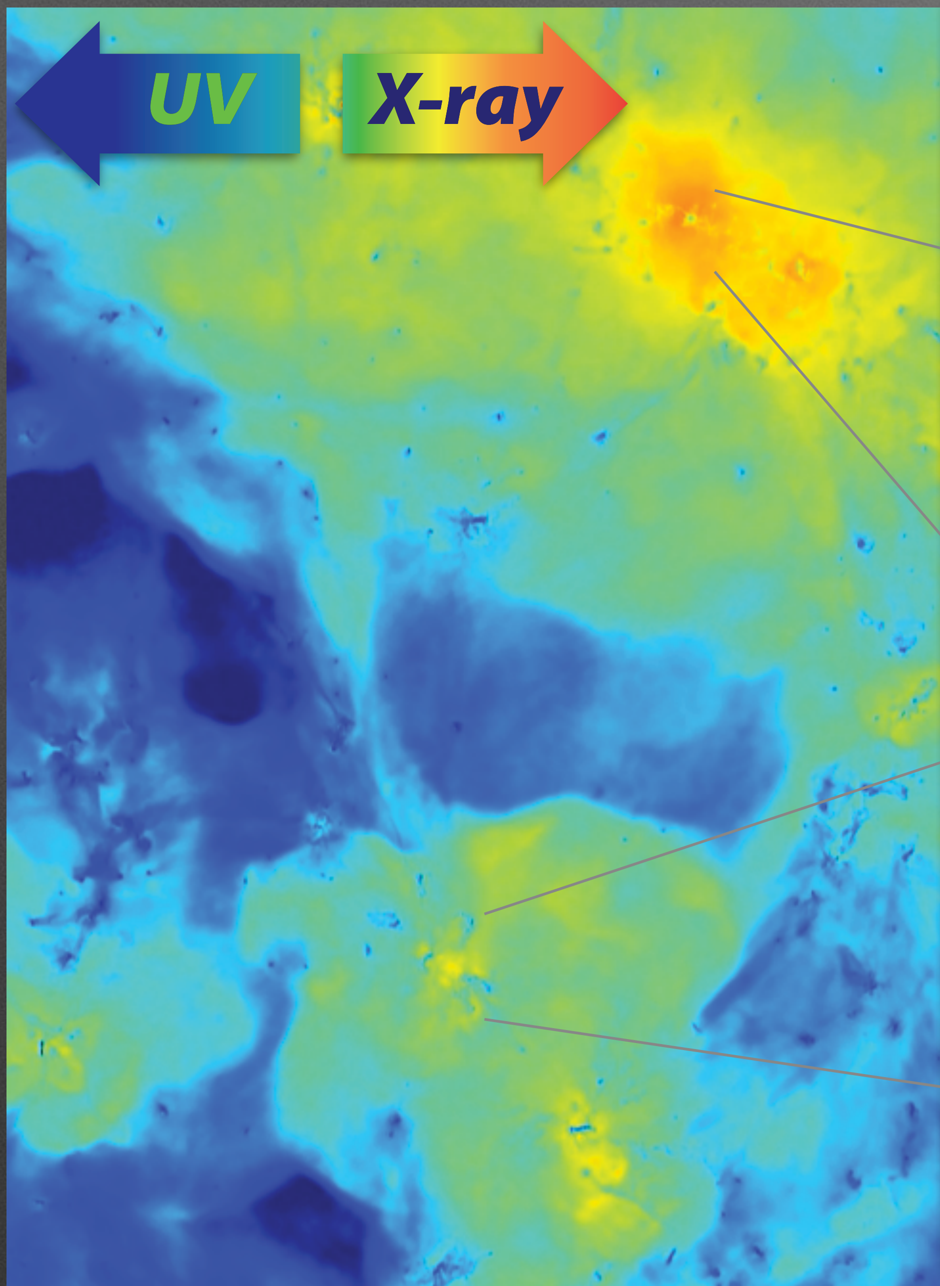
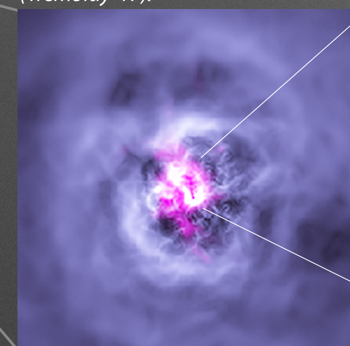
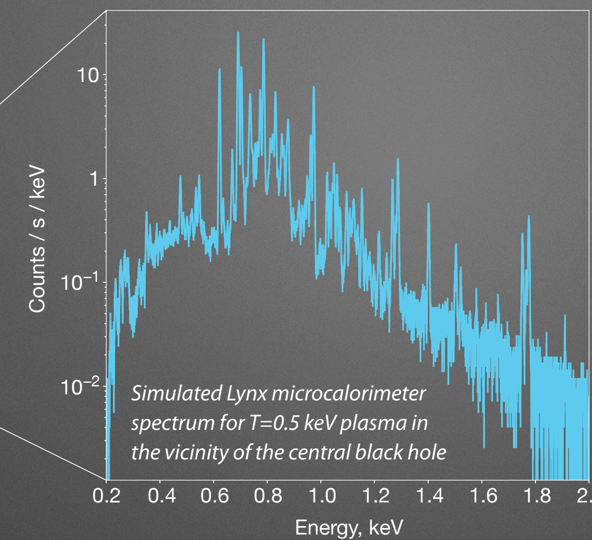


Feedback

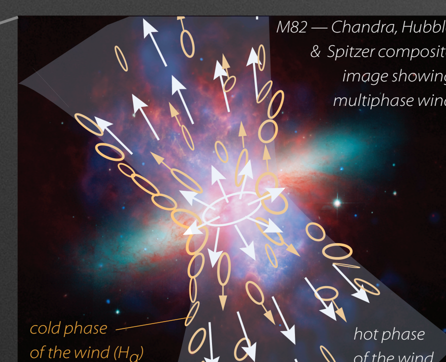
A2597 cluster — Chandra/X-ray (blue) and VLT-MUSE/H_α (purple) overlay (Tremblay '17).

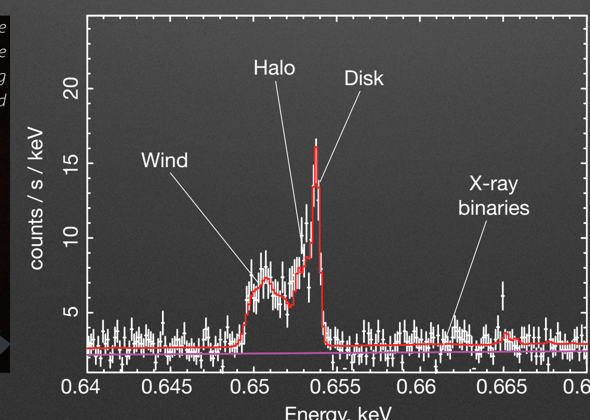




BH feedback:

- spectro-imaging of SMBH spheres of influence
- density diagnostics in AGN winds
- extended narrow emission line regions
- AGN-inflated bubbles in elliptical galaxies
- plasma physics





Galactic winds feedback:

- Spatially and spectrally resolve hot phase of galactic winds with 0.3 eV energy resolution microcalorimeter subarray

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The Energetic Side of Stellar Evolution and Stellar Ecosystems

Endpoints of stellar evolution

Stellar birth, coronal physics, feedback

Impact of stellar activity on habitability of planets

Lynx will probe with unprecedented depth a wide range of high-energy processes that provide a unique perspective on stellar birth and death, internal stellar structure, star-planet interactions, the origin of elements, and violent cosmic events. *Lynx* will detect X-ray emission as markers of young stars in active star forming regions, study stellar coronae in detail, and provide essential insight into the impact of stellar XUV flux and winds on habitability of their planets. Images and spectra of supernova remnants in Local Group galaxies will extend studies of stellar explosions and their aftermath to different metallicity environments. *Lynx* will expand our knowledge of collapsed stars through sensitive studies of X-ray binaries in galaxies as distant as 10 Mpc and detailed follow-ups of gravitational wave events. *Lynx will greatly extend our X-ray grasp throughout the Milky Way and nearby galaxies by combining for the first time the required sensitivity, spectral resolution, and sharp vision to see in crowded fields.*

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Substantial X-ray activity is a unambiguous marker for young stars (t < 600 Myr). Combined X-ray and IR data tell us when protoplanetary disks dissipate. Diffuse X-ray emission traces feedback processes.

Chandra sensitivity reaches across the stellar mass scale in young clusters only to Orion Nebula (d = 410 pc). *ATHENA* will be confused in cluster cores beyond250 pc. Lynx will reach into very active and massive OB clusters in the Carina-Sagittarius arm of the MW. Outside the cores, *Lynx* can study regions, such as NGC6357 shown above, to d ≈ 5 kpc.

Lynx Topics: *X-rays from protostars; protoplanetary disk dissipation time scales; census of young stars in clusters of different types; dust grain properties; diffuse ISM emission and feedback from stellar winds and SNe.*

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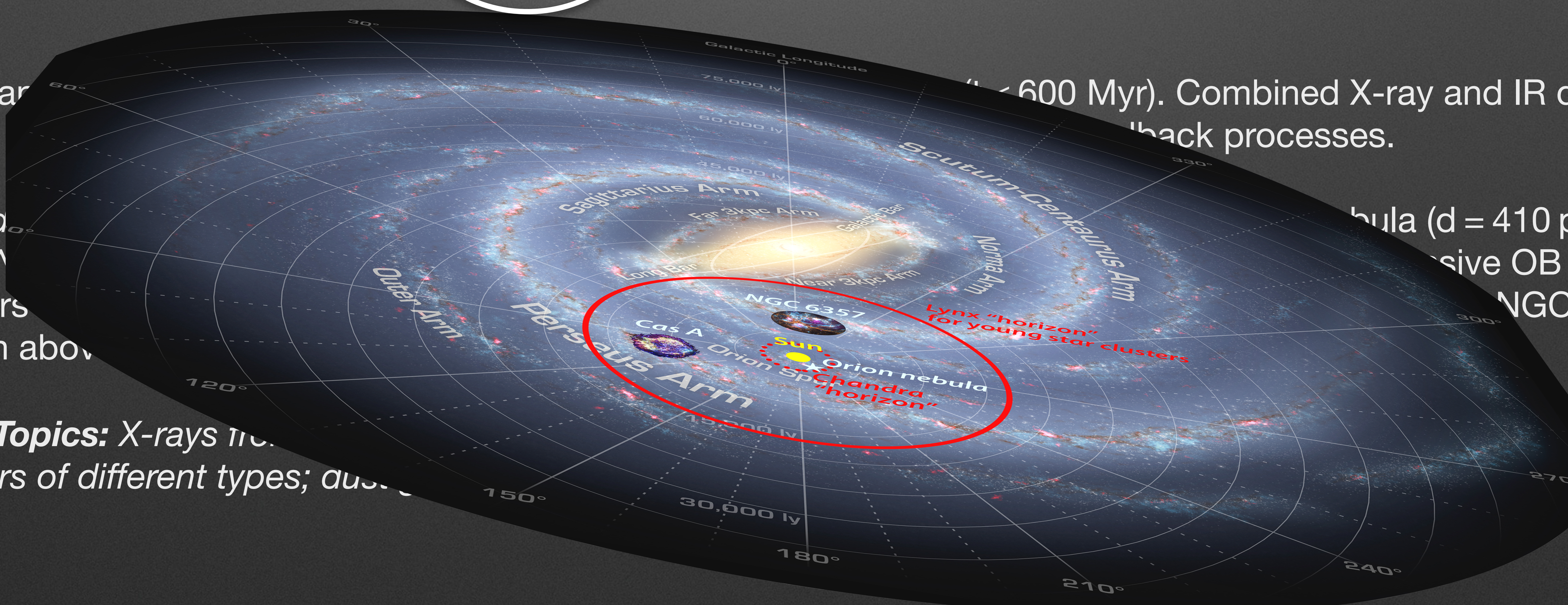

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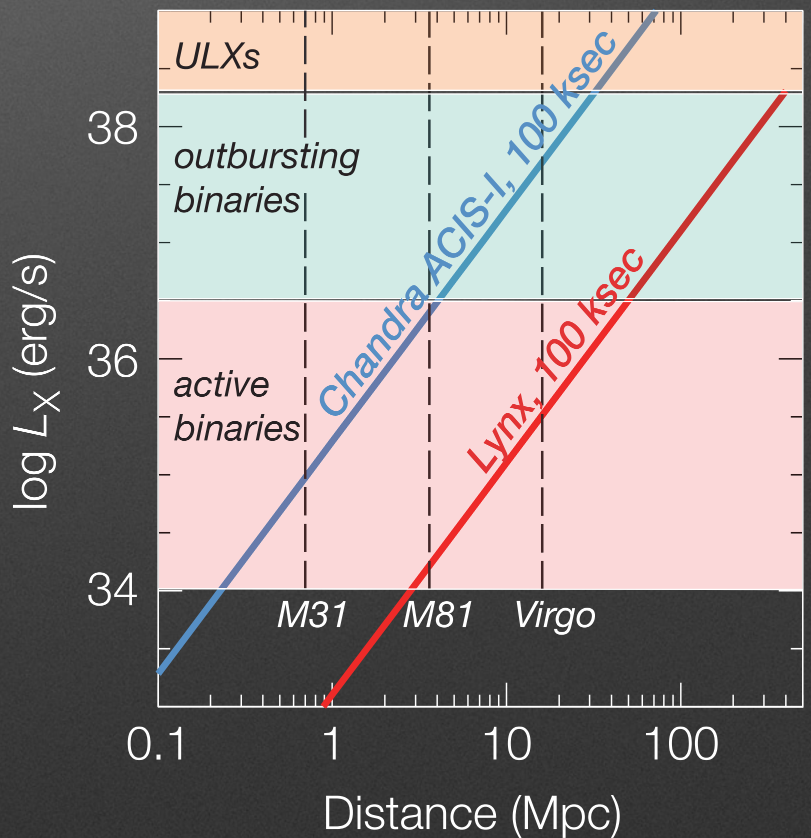
SNRs:

- 3D maps of dozens of remnants, revolutionizing constraints from SNRs on the explosion physics
- resolve the LMC & SMC remnants and establish parent SN types within the Local Group, providing a census of stellar explosions in different metallicity environments.
- young neutron stars in MW currently missed due to lack of sensitivity
- spectral studies of recent core-collapse SNe within ~10 Mpc will probe the circumstellar material ejected in the few thousand years preceding explosion.



X-ray Binaries: XRB populations in dozens of nearby galaxies down to $L_X \sim 10^{34}$–10^{35} erg/s; binary evolution models; evolutionary paths to LIGO sources.

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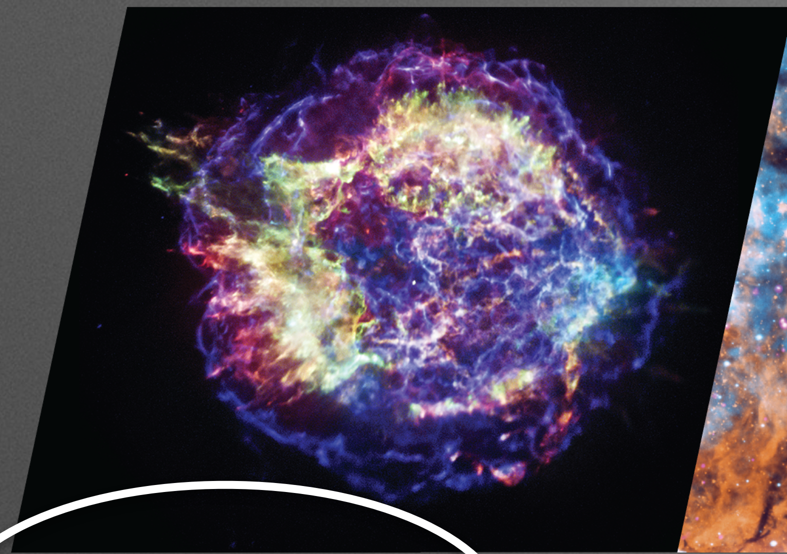

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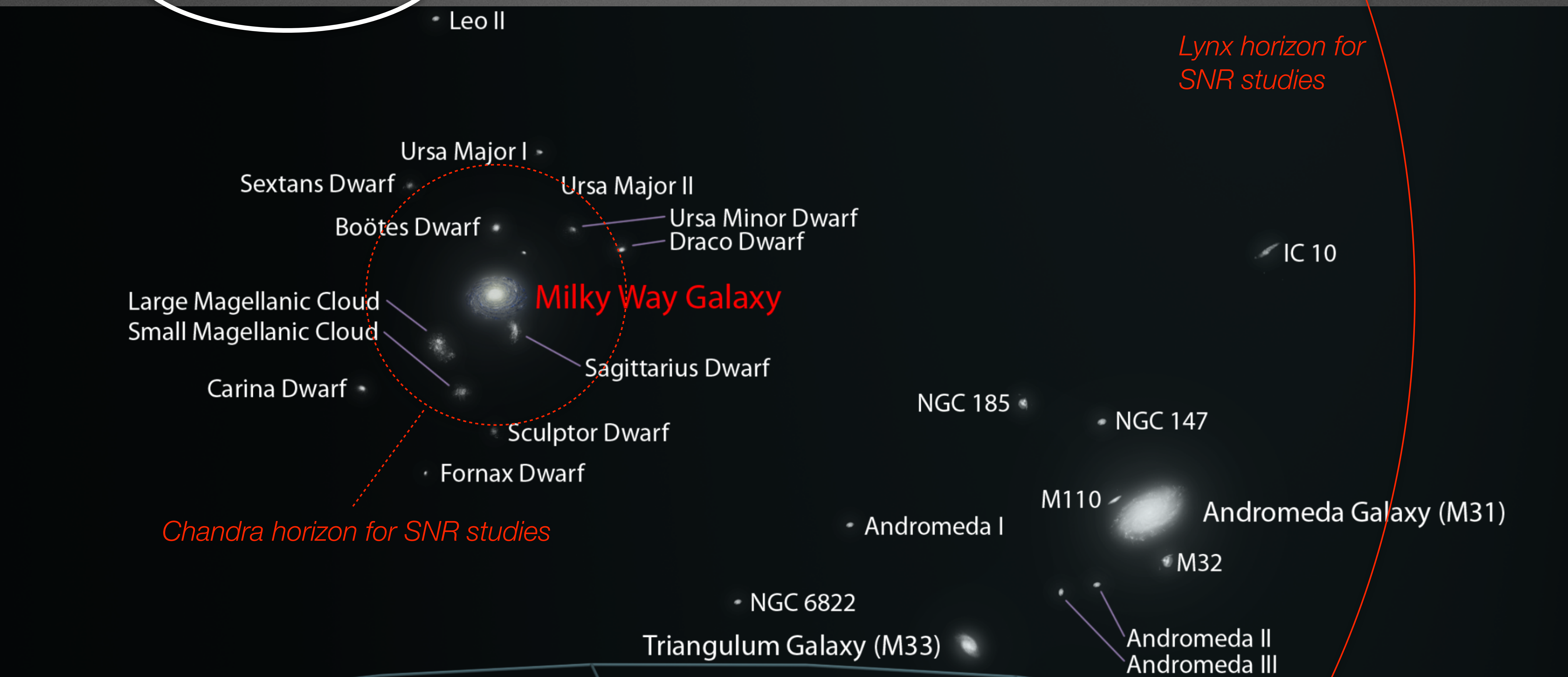

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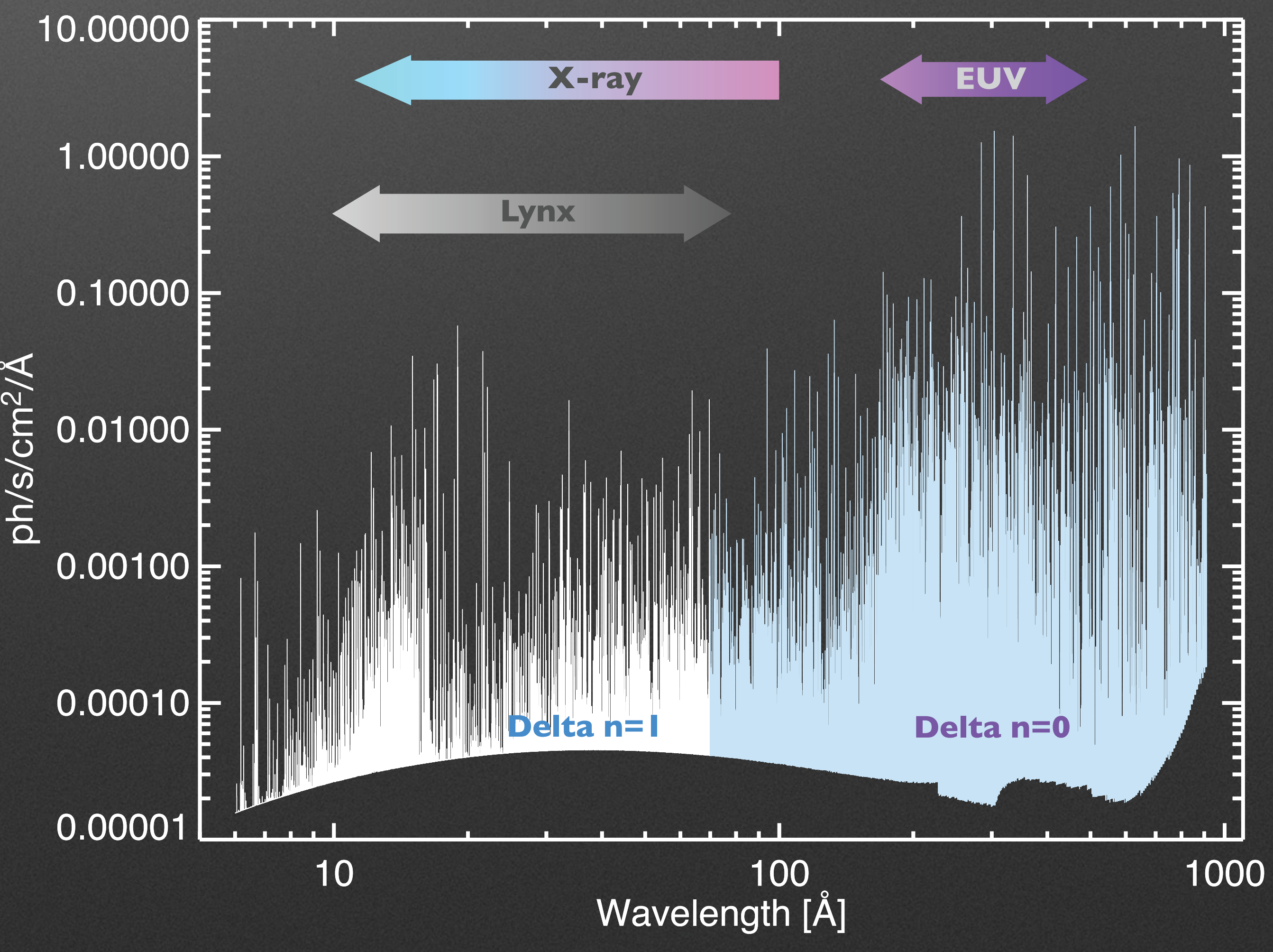
Very high resolution observations with *Lynx* gratings will resolve triplet, satellite, and dielectric recombination lines from C, N, O, Ne, Mg, Fe (K, L, and M-shells) in stellar coronae. This will provide the first precise diagnostics of T, n_e, velocities, and sizes of emission regions in stellar coronal structures. X-ray measurements can be used to project a large portion of EUV flux, which is not directly observable.

Lynx will reach as far as the Orion Nebula for detailed studies of stellar coronae, covering the full range of stellar types and ages.

Model X-ray to EUV spectrum of Proxima Cen.



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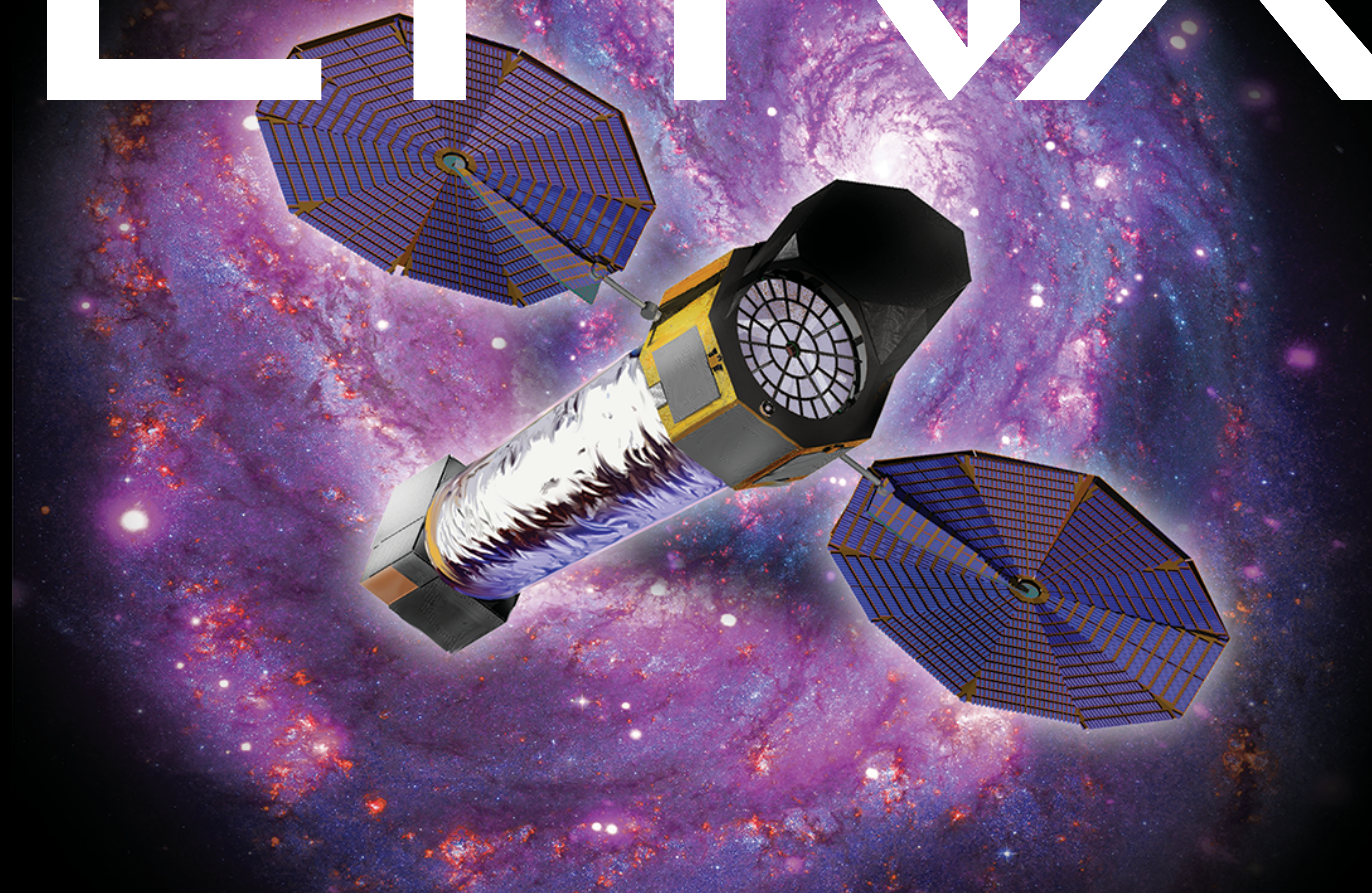

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